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Claims

What is claimed is:

1. A method for the production of a polymer having at least one unit that contains at least one cyclopentanone structure condensed with at least two aromatic rings, the method comprising:

passing an electric current between two or more electrodes immersed in an electrolytic mixture comprising an ester, an electrolyte and an aromatic compound having at least one cyclopentane structure condensed with at least two aromatic rings.

2. The method of claim 1 wherein the electrolyte in the electrolytic mixture comprises of one or more of LiPF_6 , NaPF_6 , KPF_6 , LiBF_4 , NaBF_4 , KBF_4 , $(\text{CH}_3)_4\text{NPF}_6$, $(\text{CH}_3)_4\text{NBF}_4$, $(\text{C}_2\text{H}_5)_4\text{NPF}_6$, and $(\text{C}_2\text{H}_5)_4\text{NBF}_4$.

3. The method of claim 1 wherein the electrolytic mixture further comprises a solvent.

4. The method of claim 3 wherein the solvent dissolves the ester.

5. The method of claim 1 wherein the ester is selected from the group consisting of a simple ester, a carbonic ester, a lactone, a complex ester, and mixtures thereof.

6. The method of claim 1 wherein the ester is a simple ester selected from the group consisting of methyl formate, ethyl formate, methyl acetate, ethyl acetate, methyl propionate, ethyl propionate, methyl butyrate, and mixtures thereof.

7. The method of claim 1 wherein the ester is a lactone selected from the group consisting of β -propiolactone, γ -butyrolactone, δ -valerolactone, ϵ -caprolactone, and mixtures thereof.

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8. The method of claim 1 wherein the ester is a carbonic ester selected from the group consisting of ethylene carbonate, propylene carbonate, butylene carbonate, dimethyl carbonate, diethyl carbonate, ethyl methyl carbonate, and mixtures thereof.

5 9. The method of claim 3 wherein the solvent is selected from the group consisting of acetonitrile, propionitrile, benzonitrile, nitromethane, nitroethane, nitrobenzene, tetrahydrofuran, diethyl ether, dimethoxyethane, dioxane, dichloromethane, dichloroethane, benzene, toluene, chlorobenzene, fluorobenzene, and mixtures thereof.

10 10. The method of claim 1 wherein the concentration of ester in the mixture is greater than 20% by volume.

11. The method of claim 1 further comprising one or more electrodes used as reference electrodes for voltage control.

15 12. The method of claim 1 wherein the electrodes are comprised of one or more of platinum, nickel, stainless steel, copper, carbon, PbO₂, and titanium coated with platinum or PbO₂.

20 13. The method of claim 1 wherein the electrolytic mixture further comprises a polymer having at least one unit having at least one cyclopentane structure condensed with at least two aromatic rings.

14. The method of claim 13 wherein the polymer is deposited on one or more electrodes.

25 15. The method of claim 1 wherein the concentration of aromatic compound having at least one cyclopentane structure condensed with at least two aromatic rings is in the range of 0.001-1 mol/L.

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16. The method of claim 1 wherein the concentration of electrolyte is in the range 0.001-1 mol/L.

17. The polymer produced according to the method of claim 1.

18. The polymer of claim 17 comprising at least 10% by weight units having at least one cyclopentanone structure condensed with at least two aromatic rings.

19. The polymer of claim 17 comprising at least 50% by weight units having at least one cyclopentanone structure condensed with at least two aromatic rings.

20. The polymer of claim 17 comprising at least 80% by weight units having at least one cyclopentanone structure condensed with at least two aromatic rings.

21. The method of claim 1 wherein the a polymer having at least one unit that contains at least one cyclopentanone structure condensed with at least two aromatic rings is poly(9-fluorenone) and the aromatic compound having at least one cyclopentane structure condensed with at least two aromatic rings is fluorene.

22. The method of claim 1 wherein the a polymer having at least one unit that contains at least one cyclopentanone structure condensed with at least two aromatic rings is poly(cyclopenta[def]phenanthrene-4-one) and the aromatic compound having at least one cyclopentane structure condensed with at least two aromatic rings is 4H-cyclopenta[def]phenanthrene.

23. The method of claim 1 wherein the a polymer having at least one unit that contains at least one cyclopentanone structure condensed with at least two aromatic rings is poly(8H-cyclopenta[def]fluoren-4-one) and the aromatic compound having at least one cyclopentane structure condensed with at least two aromatic rings is 4,8-dihydro-cyclopenta[def]fluorene.

24. The method of claim 1 wherein the a polymer having at least one unit that contains at least one cyclopentanone structure condensed with at least two aromatic rings is poly(cyclopenta[def]fluorene-4,8-dione) and the aromatic compound having at least one cyclopentane structure condensed with at least two aromatic rings is 4,8-dihydro-cyclopenta[def]fluorene.

25. The method of claim 1 wherein the a polymer having at least one unit that contains at least one cyclopentanone structure condensed with at least two aromatic rings is poly(benzo[b]fluoren-11-one) and the aromatic compound having at least one cyclopentane structure condensed with at least two aromatic rings is 11H-benzo[b]fluorene.

26. The method of claim 1 wherein the a polymer having at least one unit that contains at least one cyclopentanone structure condensed with at least two aromatic rings is poly(dibenzo[b,h]fluoren-12-one) and the aromatic compound having at least one cyclopentane structure condensed with at least two aromatic rings is 12H-dibenzo[b,h]fluorene.

27. The method of claim 1 wherein the a polymer having at least one unit that contains at least one cyclopentanone structure condensed with at least two aromatic rings is poly(indeno[1,2-b]fluorene-6,12-dione) and the aromatic compound having at least one cyclopentane structure condensed with at least two aromatic rings is 6,12-dihydro-indeno[1,2-b]fluorene.

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28. A method for the production of a polymer having at least one unit that contains at least one cyclopentanone structure condensed with at least two aromatic rings, the method comprising:

passing an electric current between two or more electrodes immersed in an electrolytic mixture comprising an ester and an electrolyte, wherein one or more of the electrodes includes an aromatic compound polymer having at least one unit of a at least one cyclopentane structure condensed with at least two aromatic rings.

29. The method of claim 28 wherein the electrolyte in the electrolytic mixture comprises an electrolyte selected from the group consisting essentially of LiPF_6 , NaPF_6 , KPF_6 , LiBF_4 , NaBF_4 , KBF_4 , $(\text{CH}_3)_4\text{NPF}_6$, $(\text{CH}_3)_4\text{NBF}_4$, $(\text{C}_2\text{H}_5)_4\text{NPF}_6$, $(\text{C}_2\text{H}_5)_4\text{NBF}_4$, and mixtures thereof.

30. The method of claim 28 wherein the mixture further comprises a solvent.

31. The method of claim 28 wherein the ester is selected from the group consisting of a simple ester, a carbonic ester, a lactone, a complex ester, and mixtures thereof.

32. The method of claim 28 wherein the ester is a simple ester selected from the group consisting of methyl formate, ethyl formate, methyl acetate, ethyl acetate, methyl propionate, ethyl propionate, methyl butyrate, and mixtures thereof.

33. The method of claim 28 wherein the ester is a lactone selected from the group consisting of β -propiolactone, γ -butyrolactone, δ -valerolactone, ϵ -caprolactone, and mixtures thereof.

34. The method of claim 28 wherein the ester is a carbonic ester selected from the group consisting of ethylene carbonate, propylene carbonate, butylene carbonate, dimethyl carbonate, diethyl carbonate, ethyl methyl carbonate, and mixtures thereof.

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35. The method of claim 28 wherein the concentration of ester in the mixture is greater than 20% by volume.

36. The method of claim 28 further comprising one or more electrodes used as reference electrodes for voltage control.

37. The method of claim 28 wherein the electrodes are comprised of one or more of platinum, nickel, stainless steel, copper, carbon, PbO_2 , and titanium coated with platinum or PbO_2 .

38. The method of claim 28 wherein the aromatic compound polymer having at least one unit of at least one cyclopentane structure condensed with at least two aromatic rings is deposited on the one or more electrodes.

39. The method of claim 28 wherein the aromatic compound polymer having at least one unit of at least one cyclopentane structure condensed with at least two aromatic rings is comprised of at least 10% by weight units that contain at least one cyclopentane structure condensed with at least two aromatic rings.

40. The method of claim 28 wherein the aromatic compound polymer having at least one unit of at least one cyclopentane structure condensed with at least two aromatic rings is comprised of at least 50% by weight units that contain at least one cyclopentane structure condensed with at least two aromatic rings.

41. The polymer produced according to claim 28.

42. The polymer of claim 41 comprising at least 10% by weight units that contain at least one cyclopentanone structure condensed with at least two aromatic rings.

43. The polymer of claim 41 comprising at least 50% by weight units that contain at least one cyclopentanone structure condensed with at least two aromatic rings.

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44. The polymer of claim 41 comprising at least 80% by weight units that contain at least one cyclopentanone structure condensed with at least two aromatic rings.

45. The method of claim 28 wherein the concentration of electrolyte is in the range 0.001-
5 1 mol/L.

46. The method of claim 28 further comprising one or more electrodes used as reference electrodes for voltage control.

10 47. The method of claim 28 wherein the polymer having at least one unit that contains at least one cyclopentanone structure condensed with at least two aromatic rings is poly(9-fluorenone) and the aromatic compound polymer having at least one unit of at least one cyclopentane structure condensed with at least two aromatic rings is poly(fluorene).

15 48. The method of claim 28 wherein the polymer having at least one unit that contains at least one cyclopentanone structure condensed with at least two aromatic rings is poly(cyclopenta[def]phenanthren-4-one) and the aromatic compound polymer having at least one unit of at least one cyclopentane structure condensed with at least two aromatic rings is poly(4H-cyclopenta[def]phenanthrene).

20 49. The method of claim 28 wherein the polymer having at least one unit that contains at least one cyclopentanone structure condensed with at least two aromatic rings is poly(8H-cyclopenta[def]fluoren-4-one) and the aromatic compound polymer having at least one unit of at least one cyclopentane structure condensed with at least two aromatic rings is poly(4,8-dihydro-cyclopenta[def]fluorene).
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50. The method of claim 28 wherein the polymer having at least one unit that contains at least one cyclopentanone structure condensed with at least two aromatic rings is poly(cyclopenta[def]fluorene-4,8-dione) and the aromatic compound polymer having at least one

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unit of at least one cyclopentane structure condensed with at least two aromatic rings is poly(4,8-dihydro-cyclopenta[def]fluorene).

51. The method of claim 28 wherein the polymer having at least one unit that contains at least one cyclopentanone structure condensed with at least two aromatic rings is poly(benzo[b]fluoren-11-one) and the aromatic compound polymer having at least one unit of at least one cyclopentane structure condensed with at least two aromatic rings is poly(11H-benzo[b]fluorene).

52. The method of claim 28 wherein the polymer having at least one unit that contains at least one cyclopentanone structure condensed with at least two aromatic rings is poly(dibenzo[b,h]fluoren-12-one) and the aromatic compound polymer having at least one unit of at least one cyclopentane structure condensed with at least two aromatic rings is poly(12H-dibenzo[b,h]fluorene).

53. The method of claim 28 wherein the polymer having at least one unit that contains at least one cyclopentanone structure condensed with at least two aromatic rings is poly(indeno[1,2-b]fluorene-6,12-dione) and the aromatic compound polymer having at least one unit of at least one cyclopentane structure condensed with at least two aromatic rings is poly(6,12-dihydro-indeno[1,2-b]fluorene).

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54. A method for the production of a polymer having at least one unit that contains at least one cyclopentanone structure condensed with at least two aromatic rings, the method comprising:

chemically oxidizing an aromatic compound polymer having at least one unit that contains at least one cyclopentane structure condensed with at least two aromatic rings with a chemically prepared oxidizing agent.

55. The method of claim 54 wherein the chemically prepared oxidizing agent is selected from the group consisting of alkali metal salts of bichromic acid (bichromates), alkali metal salts of permanganic acid (permanganates), percarboxylic acids, and mixtures thereof.

56. The method of claim 54 wherein the oxidizing step is carried out at a temperature in the range of 20-180 degrees Celsius.

57. The method of claim 54 wherein the aromatic compound polymer having at least one unit that contains at least one cyclopentane structure condensed with at least two aromatic rings is dissolved or suspended in a solvent, the solvent is selected from the group consisting essentially of aliphatic carboxylic acids, fluorinated aliphatic carboxylic acids, halogenated hydrocarbons, water, and mixtures thereof.

58. The method of claim 54 wherein the molar ratio of oxygen atoms available from an oxidizing agent to a unit within the polymer is at least 0.5.

59. The polymer produced according to claim 54.

60. The polymer of claim 59 comprising at least 10% by weight units that contain at least one cyclopentanone structure condensed with at least two aromatic rings.

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61. The polymer of claim 59 comprising at least 50% by weight units that contain at least one cyclopentanone structure condensed with at least two aromatic rings.

62. The polymer of claim 59 comprising at least 80% by weight units that contain at least one cyclopentanone structure condensed with at least two aromatic rings.

63. The method of claim 59 wherein the polymer having at least one unit that contains at least one cyclopentanone structure condensed with at least two aromatic rings is poly(fluorenone) and the aromatic compound polymer having at least one unit that contains at least one cyclopentane structure condensed with at least two aromatic rings is poly(fluorene).

64. The method of claim 54 wherein the polymer having at least one unit that contains at least one cyclopentanone structure condensed with at least two aromatic rings is poly(cyclopenta[def]phenanthren-4-one) and the aromatic compound polymer having at least one unit that contains at least one cyclopentane structure condensed with at least two aromatic rings is poly(4H-cyclopenta[def]phenanthrene).

65. The method of claim 54 wherein the polymer having at least one unit that contains at least one cyclopentanone structure condensed with at least two aromatic rings is poly(8H-cyclopenta[def]fluoren-4-one) and the aromatic compound polymer having at least one unit that contains at least one cyclopentane structure condensed with at least two aromatic rings is poly(4,8-dihydro-cyclopenta[def]fluorene).

66. The method of claim 54 wherein the polymer having at least one unit that contains at least one cyclopentanone structure condensed with at least two aromatic rings is poly(cyclopenta[def]fluorene-4,8-dione) and the aromatic compound polymer having at least one unit that contains at least one cyclopentane structure condensed with at least two aromatic rings is poly(4,8-dihydro-cyclopenta[def]fluorene).

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67. The method of claim 54 wherein the polymer having at least one unit that contains at least one cyclopentanone structure condensed with at least two aromatic rings is poly(benzo[*b*]fluoren-11-one) and the aromatic compound polymer having at least one unit that contains at least one cyclopentane structure condensed with at least two aromatic rings is poly(11H-benzo[*b*]fluorene).

68. The method of claim 54 wherein the polymer having at least one unit that contains at least one cyclopentanone structure condensed with at least two aromatic rings is poly(dibenzo[*b,h*]fluoren-12-one) and the aromatic compound polymer having at least one unit that contains at least one cyclopentane structure condensed with at least two aromatic rings is poly(12H-dibenzo[*b,h*]fluorene).

69. The method of claim 54 wherein the polymer having at least one unit that contains at least one cyclopentanone structure condensed with at least two aromatic rings is poly(indeno[1,2-*b*]fluorene-6,12-dione) and the aromatic compound polymer having at least one unit that contains at least one cyclopentane structure condensed with at least two aromatic rings is poly(6,12-dihydro-indeno[1,2-*b*]fluorene).

70. A light-emitting diode comprising the polymer produced according to claim 1.

71. A light-emitting diode of claim 70 wherein the light-emitting diode is a multilayer light-emitting diode.

72. A light-emitting diode comprising the polymer produced according to claim 28.

73. The light-emitting diode of claim 72 wherein the light-emitting diode is a multilayer light-emitting diode.

74. A light-emitting diode comprising the polymer produced according to claim 54.

75. The light-emitting diode of claim 74 wherein the light-emitting diode is a multilayer light-emitting diode.

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